Climate Webinar – June 24, 2014

Thank you all for standing by and welcome to our June webinar entitled 'Climate Change and Harmful Algal Blooms in Maumee Bay'. These webinars are an initiative of The Ohio State University Climate Change Outreach Team, a multi-departmental effort within the university led by Ohio Sea Grant, Office of Research, Ohio Supercomputer, OSU Extension, and eight other OSU departments to help localize the climate change issue for Ohioans and Great Lakes residents. I'm Jill Jentes Banicki from Ohio Sea Grant and Stone Laboratory, and joining me today is Dr. Jay Martin. Dr. Martin is a professor in the department of Food, Agricultural, and Biological Engineering at Ohio State University, and is an ecological engineer with expertise in both hydrology and ecosystem modeling. His research focuses on interactions between watersheds and downstream ecosystems. Prior to this project that investigates connections between water quality in the Maumee Bay and the upstream watershed he completed similar projects in the Sandusky watershed, and Mississippi Delta Gulf of Mexico. We're delighted to have him here today to talk to us about climate change and harmful algal blooms in Lake Erie's Maumee Bay.

But before we get started a few logistical issues. During our presentation all participants will be in a listen-only mode. Afterwards I will conduct a question and answer session. If you would like to ask a question during the presentation, please feel free to use the 'chat' feature located on the right-hand side of your screen, and I will collect and pose your questions out to Dr. Martin at the end of his presentation. We have more than 150 participants on this webinar, a great diverse group representing governmental agencies, academia, and nonprofit groups from the Great Lakes and around the country. Please keep those questions coming throughout the presentation, and we should have a great Q&A session. As a reminder this webinar is being recorded and will be posted onto our website for later viewing. Also, we will post a webinar survey in the 'chat' feature towards the end of the hour. Please take a few minutes after the webinar to fill out that survey. It will help us continue to bring you better webinars.

So without any further delay, I'd like to introduce Dr. Jay Martin from Ohio State University who will present 'Changes in Climate in the Maumee Basin and Impacts on Harmful Algal Blooms in Lake Erie'. Dr. Martin, you should be all set.

Great! First of all, I want to thank Jill and Christina and everybody else at Ohio Sea Grant for inviting me to be a part of this webinar today, and thanks to everyone else for tuning in. You appreciate being here. And with that I'm going to go ahead and get started.

So first of all, I just want to acknowledge my coauthors. They've done a lot of work, especially Seyoum Gebremariam. He's an excellent post-doc who has done the lion's share of the work here. So any mistakes I might make are solely due to myself, and not due to my coauthors. With that I'm going to go into a little bit of background and objectives. So a couple of years ago the world Resources Institute identified approximately over 750 coastal areas that are being degraded by eutrophication/hypoxia across the world. The one thing all these have in common is the eutrophication/hypoxia is due almost solely to greater amounts of nutrients coming from the upstream watershed and in-stream coastal or lake systems. And this causes eutrophication or hypoxia.

So this is a global problem, and it's also occurring in Lake Erie. And so these are pictures of the cyanobacterial blooms in Lake Erie. Those of you who've looked in this problem know that this has great economic public health impacts, so economically there's over a billion dollar fishing industry that's impacted by this. Many people who enjoy recreation on Lake Erie, it's obviously impacted by these events. Last year there was a water plant that had to be closed in Toledo, so these have great implications on how we live our lives and economic returns from the Lake Erie area.

So, you know, these have been happening in the past, and so the big question is what should we expect in the future? When we look at harmful algal blooms (HABs) in general, not just on Lake Erie, there have been a couple recent reports, and if we go back in the past more reports, that these events are expected to increase in magnitude and extent in the future. Why is this going to happen? There's at least three reasons why we expect these harmful algal blooms to increase in the future. With climate change and warmer climates we see longer growing seasons. This is going to increase the opportunity that these organisms can grow. We also expect to see wetter and stormy winters and springs in the future, especially in the Midwest, which impacts the Great Lakes and Lake Erie. So because of this we expect to see an increase in nutrients coming into the lakes, which will increase the photosynthetic rate. Lastly, with higher CO_2 emissions and higher CO_2 concentrations in the atmosphere, this will increase the dissolved organic carbon or DOC, and this will also increase the photosynthetic rate. So there's three general reasons why we expect harmful algal bloom events to become greater in magnitude in the future.

When we zero in on the Great Lakes and especially Lake Erie, we wonder if this is going to happen in Lake Erie? A recent report by Michalak et al. said this is going to happen in Lake Erie. But these predictions for the Great Lakes or for Lake Erie especially are based on historical trends, and there's really no, there's been no one to look into future climate scenarios and analyze the impacts of future climate scenarios on these HAB events.

So that leads to the objective and method of our study, which the objective was to assess the impact of hydroclimatic change on cyanobacterial bloom outbreaks in Lake Erie (LE). And so the method I've outlined here very primitively with these three pictures. So what we wanted to do is to look at climate models that exist. There's many good climate models. Use these climate models to predict precipitation and temperature in the future, and then use this precipitation and temperature to drive watershed models. And these watershed models will predict future river discharge, which includes not only the river discharge, but also discharge of nutrients and sediments. And then use this river discharge including water quality changes in the future to drive HAB models, and with this we'll be able to predict the frequency and size of HAB events into the future. So that's our objective and a schematic of our method.

And so with that we'll go into the methods and the study system a little bit more. I'd like to start with general introduction to Lake Erie. This is a picture of LE here. It's usually divided into three different areas, the west, the central, and the east. And the west is where the greatest amount, the highest intensity of HAB events have historically occurred, and this is because of the geomorphology of LE. So LE when you look at the western portion of LE, it has the highest amount of productivity. Why is this? One of the reasons is because it's also the shallowest portion of the lake, so the greater proportion of the lake is a photic zone, so it's exposed to the sun. There's a large amount of nutrients that come in from the Maumee Basin. And when you put these two things together you have a very productive system, which lends itself well to HAB events.

So when we look a little closer at the western basin, at the very furthest edge of the western basin, the furthest western portion of the western basin is where the Maumee River enters LE. And the Maumee River discharge really drives what happens in LE, especially related to HAB events. So the Maumee River drives the dynamics of the phosphorus that comes into LE, which drives the HAB events. It drives water clarity, as I mentioned it drives HAB events, and these are also related to fish recruitment. This is a little bit counterintuitive because the vast amount of water that comes into LE comes from the north from the Detroit River, which I'm highlighting here with the pointer. Entrance from the Maumee River comes in from the western portion, but the Maumee River, while it brings in not the majority of the water, still does contribute the majority of the phosphorus, and because of this it drives most of the dynamics as related to HABs, fish recruitment, and other important things that happen in LE. So the bottom line here is that if you want to predict what's happening in LE is you need to have a very good model, very good predictions of what's coming out of the Maumee River.

This is a better map of the watershed of the Maumee River, so you can see where Toledo is. That's where the Maumee River enters LE. You can see some of the larger cities in the Maumee Basin, and it lies at the intersection of the three states, Michigan, Indiana, and Ohio. The bulk of the watershed is in Ohio. The main thing I want to point out here is that the watershed is dominated by agriculture, about 70-80% of the watershed is covered by agriculture, most of that is row crop predominantly soybean and corn farms. And the point to take from here is that those soybean and corn farms are fertilized with a large amount of phosphorus, and the phosphorus then runs off these fields through the smaller rivers and eventually comes into LE. And there's pretty good agreement that most of the phosphorus that comes into LE is due to these agricultural inputs. There's smaller amounts that are due to CSO events and municipal wastewater discharges, but the bulk of the phosphorus coming into LE is from agriculture, and this basin is dominated by agriculture.

So now I'd like to go into the methods and look into the climate models we use. So again going back to that schematic, one of our first goals was to predict the future climate and use that to drive the watershed models. So to determine the precipitation and temperature in the Maumee Basin we used 36 different global climate models, and looked at a period of time from 1950-2099. This is a subset of the 36 climate models we used, and to those of you who know a lot about climate modeling these acronyms might mean something to you. They don't mean that much to me actually to be honest to you. I am highlighting this one, the first climate model here, the BCC model, and I'm going to come back to that as we move through the precipitation and refer specifically to the results of the BCC. I'm also going to refer specifically to results from CanESM2 model and also the CSIRO model here. Unfortunately we haven't been able to run through all of the results for these climate models with HAB events. We have been able to go through all 36 with regards to future precipitation.

Those of you who are familiar with climate modeling know that now the IPCC has four different scenarios they're talking about for representative carbon pathways. So if we look at the graph here, we see that there's four different RCP scenarios, where 'RPC' stands for 'representative carbon pathways'. So all of them start in the present with about 370 ppm CO_2. The best-case scenario here, which is the green, is the RCP scenario of 2.6 comes out in 2100 with a CO_2 concentration of about 400 ppm. If we look at the worst-case scenario with a RCP of 8.5, we have a CO_2 concentration of over 900 ppm at 2100. So what we've done to simplify our predictions is we've looked at the best-case and worst-case RCP scenarios, so as I move through this presentation I'm going to show results for RCP 2.6 and RCP 8.5. Just due to time limitations and the amount of time it takes to run these scenarios we have neglected so far to do RCP 4.5 and RCP 6. But the idea is that RCP 2.6 and RCP 8.5 will bound predictions.

So now onto the watershed model. Again, once we can predict the future rainfall from the climate models we can use that rainfall to drive watershed models. So what we've done here is we've used a SWAT, which is an acronym for the Soil and Water Assessment Tool, so we've used a SWAT model of the Maumee Basin. The SWAT model is the leading watershed model for agricultural watersheds, so it makes a lot of sense to use that here for the Maumee Basin. You can see some statistics here about the Maumee Basin, the area. Those of you who know more about SWAT modeling will be interested to know there's 252 watersheds we've used for the SWAT model. We've divided that into 3000 HRUs. As we developed this model and checked it out, we've calibrated it to the basin outlet, which is identified here at Toledo.

One thing that's really nice about the Maumee Basin is there's a pretty good amount of data with regards to discharge and also pretty good water quality data. So not only did we calibrate the model at Toledo, but we also calibrate a model within the basin. So here I've identified five different data points within the basin that we used to calibrate the model. And as I'll show you later we're very confident that this model does a good job predicting discharge in the Maumee Basin.

So once we're able to predict climate and then use the watershed to take the inputs of that climate and predict what's coming out of the watershed, the next step in our project was to predict how the HABs are going to respond to changes in river discharge. To do this we used a model that's been developed by Stumpf et al. in 2012. For those of you who regularly attend this webinar will know that this model was presented earlier this year in this webinar. And here you can see the correlation. This is a very strong model. On the bottom of this graph is the Maumee River flow, and this is the Maumee River flow in the spring. And then on the vertical axis is the cyanobacterial index ranging from 10-15, and you can see it has a very high R^2. Here's the exact equation that was used. The cyanobacterial index, so an index of 1 is equal to about 300 km^2 bloom area. An index of 5 is equal to about 1500 km^2 bloom area. So it's a pretty straight-forward index. And the other thing I want to point out is we're talking about the spring discharge in the Maumee, so Stumpf et al. used just the spring discharge from March through June to get this correlation. So this is the model that we're using to predict from the discharge the Maumee River, the intensity of the HAB events. It is a little bit possibly counterintuitive. There's a lot of good evidence that shows that phosphorus is really what drives the HAB events, so a good question to ask would be why are we not using phosphorus discharge to predict the cyanobacterial index? In fact Stumpf et al. did look at that and they had a very similar model with phosphorus discharge, spring phosphorus discharge in the Maumee River, but it had a little bit lower R^2. It wasn't quite as good a model. So we went ahead and used the Maumee River discharge instead of phosphorus because it had a higher R^2, a little bit better model. We probably could have used phosphorus and gotten very similar results. I should point out that the phosphorus and the discharge are highly correlated, so if you have a high river flow you're going to have a high phosphorus discharge as well. So that's why I'm pretty confident that if we use discharge or if we use phosphorus we'll get similar results, but that's something we want to look into in the future.

So with that I'll conclude the study system and methods. Now I'd like to go into the results, and so for the results I'm going to follow the same format. We're going to talk first of all about climate and look at what's predicted for future precipitation. Then we'll look at the watershed and river discharge to take in that future precipitation and determine how that's going to impact river discharge. And then lastly we'll look at how river discharge will impact HAB events.

So I'm going to show a few graphs here, and they're fairly complicated so I wanted to take a minute and walk you through this before I put up all the different panels here on this graph. So here we're looking at the results and the future precipitation. So if we look at this first panel on the vertical side is 0-36. It shows 0-35. There's actually 36, and these are those climate models that we analyzed. And then on the bottom of this graph it shows 0-40. This is the change in March-June precipitation in mm/season. The dashed blue line you'll see in all of these panels is the baseline, so this is the baseline average rainfall that happened from 1960-1990. The solid green line, and in some cases can be a dashed green line, is the predicted mean from the 36 climate scenarios that we analyzed. So what you can see, and then sorry I'm going to take one more step back before I explain that. For each one of these we're going to divide this up into three time periods in the future. The first is going to be from 2011-2040. This is known as the near-century. Secondly, we're going to look at the results for 2041-2070; this is mid-century. And lastly we're going to look at 2071-2099, and this is what's known as end-of-century in the climate modeling circle. So if we just look at this little panel here, we see the 0 is the baseline from 1960-1990, so we've normalized everything for that baseline. And then you can see the 36 different climate models, there's a lot of variability here, but each one of them predicts an increase in precipitation compared to the baseline. And then when we look at the average here we see an average increase of maybe 35 mm of rainfall during the springtime. Okay, so when we look across the average of these 36 different climate models we see an increase of maybe 3.5 cm during the spring season.

Okay, so now we're going to see five more of these panels; actually three more right now. And at the top, at the top of each of these slides we're going to look at the low emissions. So low emissions are at the top. So each one of these three predictions is for the low emissions RCP 2.6 scenarios. Okay, so 2011-2040 we see about a 35 mm increase. When we get to 2041-2070, here we see a little bit more than a 40 mm increase of spring precipitation. When we get to the end-of-century we see that increases further to maybe 45 or something like that increase average precipitation for the Maumee basin. And again these top three are for the RCP of 2.6.

On the bottom half now I'm showing the RCP of 8.5. And here we see that in the near-century, 2011-2040, we see about 35 mm increase. When we get to the mid-century, maybe a bit more than the lower RCP scenario; maybe 45 mm increase. And then when we get to the end-of-century for the higher emission scenario, here we're up to closer to a 70 mm increase or maybe 7 cm increased rainfall for spring in the Maumee Basin. Up on top I've noted that these increases are about 10-20%, if we look at a percent increase compared to what we normally see. This 2011-2040 is close to the 10%, and this bigger increase for the RCP scenario 8.5 is about a 20% increase. So the main conclusion here by looking at future precipitation across all 36 of these models is we're going to see more precipitation in the Maumee Basin. We might predict, we might think that that precipitation is going to get a little bit bigger as we move from near-century to mid-century to end-of-century, and depending on the different CO_2 in the atmosphere we might expect bigger amounts of rainfall compared to lower amounts of CO_2 in the atmosphere. Basic bottom line: we're going to see increases in rainfall in the spring in the Maumee Basin.

I did mention before I wanted to highlight the BCC climate model here. That's the climate model we're going to look at initially. I'm just highlighting where those results show up with regards to the other 36 climate models. The reason I'm looking at this one first, it's not arbitrary. It's because it's the first one to come out alphabetically. So if you look at all the 36 climate models we analyzed, BCC was the first one alphabetically, so we started there.

Okay so we finished, so we were able to predict future climate. So the next step is to take that climate and drive watershed models. The first thing I want to do is show you that our watershed model works very well. How do we know that it works well? So we ran this watershed model and compared it to historical predictions, so we know what happened in the past. We know how much rainfall happened in the past. We know how much discharge. So we can take that historical rainfall, use that to drive our model, and then compare that model output to what actually happens, and then hopefully we get good agreement and that means our model is working pretty well. And this is just a graph of how we did that. So you can see the simulated output in blue, so this is what our model predicted from 1970-1984. And the observed values are in black. So you can see there's some disagreement, but overall we do represent the trends pretty well. Those of you who know more about watershed modeling will see these indices over here, NSE, PBIAS, and R^2. These are all very high, very strong, so very strong correlations that our model is working very well and agreeing very well with the historical discharge from the river.

So just to summarize this. So not only did we look at 1970-1984 for calibration, we also validated this from 1985-1999 and also looked at a period from 1959-1969. So for the calibration period what that means is we were able and went in and changed some of the coefficients of the model to get these results to show that we had very good agreement between what happened historically between the model and the actual data. For the validation scenarios we take the results and the calibration scenario, we don't change anything. We just run the model based on that calibration and see how good a fit we have. And so these values are a bit lower than the calibration, but still very strong numbers. So we have very good calibration, very good validation. The bottom line here is that we can reliably predict the Maumee River discharge and we know this because the values I'm presenting here are well above the published calibration thresholds. So we're able to predict climate, we're able to take that change in the precipitation from the climate, move it through these watershed models and predict changes in discharge from the Maumee River.

So these are the actual results we have of future discharge. And again what I'm presenting here as you see on the bottom of the screen is for the BCC, so we're only looking at one climate change model here, the BCC climate change model. On the left-hand side of the screen we see increase in discharge from the Maumee River for low emissions; the low emission scenario of an RCP 2.6. Again we're looking at March, April, May, and June; spring discharge is what we're interested in. And when we look across these three periods of time in the future, near-century, mid-century, and end-of-century, overall you see maybe a 30-60% increase. There's some variability here.

When we look at the high emissions scenario for the BCC model, the variability is much greater is the first thing to note here. Overall we see on average maybe a 30-60% increase again here, but we see a bigger variability, especially as we move into the end-of-century we see much bigger increases in discharge.

So how does that increase in discharge effect the cyanobacterial blooms in LE? That's what we all want to know, and that's the main point of this presentation. And I'm going to show that now. So again we're only looking at one climate change model, the BCC model. And what we're plotting here on the y-axis is the increase in bloom events relative to what happened in 2000, between 2000 and 2010. And we're looking at cyanobacterial indices of 1 or cyanobacterial events covering greater than 300 km^2. So how much will the bloom events, or what's the percent change in these bloom events with regards to what happened in 2010-2000, between 2000 and 2010? In 2011-2040 for the low RCP we see maybe a 10% increase. When we look at the low RCP 2040-2070, maybe 20%. When we look at 2071-2099 again a 10%. For these low RCP scenarios maybe a 10% increase in these bloom events with regards or in comparison with what happened between 2000 and 2010.

When we look at the RCP of 8.5 we see that these percent increase jumps from 40 to 50 or maybe 60%, okay, compared to what happened between 2000 and 2010. So increases in both, but increases are much greater for higher RCP scenarios.

When we look at larger bloom events, so here I'm talking about bloom events which are greater than 1500 km^2, and we've seen only one of these and this is what happened in 2011. So we're talking about really large bloom events. So if you look at the y-axis, we're talking again about frequency of these bloom events greater, with the cyanobacteria index greater than 5, or covering 1500 km^2, similar to what happened in 2011. So if we look at both of these RCP scenarios we see the frequency of these bloom events are going to be probably around 3 during all three of these featured climate periods. So we're talking about 30-year window here, from 2011-2040, frequency of these bloom events is going to be about 3, so about one per decade. So what's interesting here is we expect these, the frequency of these really large bloom events to remain about the same, so we've seen one of these since 2000, so that was in 2011, so one per decade historically. And then the future we also expect to see about one per decade based on this one climate model.

So what I'd like to do now, these are some new results I just added to this this morning actually. So we looked at one climate model, and what I'd like to do now is look at two more climate models. And I hope that these climate models will kind of bound our predictions. The first of these is the CSIRO model, and I mentioned this earlier, C-S-I-R-O model. And it's shown here by the larger ring. And so you can see that this model, if we look at this, and we're looking here at precipitation again. This model generally predicts larger increases in precipitation in the future, so you can see it's, when we look at 2011-2040 for the RCP 2.6, it's one of the largest predictions, it's one of the largest prediction in 2041-2070, and also 2071-2099. That trend basically continues when we look at the RCP of 8.5 with the exception of what happens here for the near-century. In contrast to this C-S-I-R-O model there's also the CANES model, and the CANES model systemically predicts smaller precipitations in the future. So you can look at that, and that's shown here with the donut. So we can look at what happened here in 2011-2041, it's one of the, predicts one of the lowest increases in precipitation, and that holds true throughout these scenarios, again there's some variability here. So what I'm going to present now is the HAB predictions based on these two climate models to kind of give us some bounds or show what the variability is between climate models that predict a large amount, or a large increase in rain versus climate models that predict a small increase in rain.

So we'll start with the CANES model, and again the CANES model is a GCM that predicts a lower amount of precipitation. So on the vertical axis here we're talking about the increase in bloom events relative to 2000-2010 with a cyanobacterial index of one. This is just your basic bloom event. What's the percent increase in bloom events we'll see? And you can see here that, you know, there's an on average increase of maybe 30-35% or something, but there's a lot of variability. So one of the things that's interesting for the high RCP scenario of 8.5 in mid-century there's this 0% increase. This is not missing data, there's actually a 0% increase we expect. In contrast, there's about a 75% increase at the end-of-century for the high RCP scenario. But there is a wide range ranging from a 0% to 75%; on average maybe 30-35% increase in HABs events in LE from a GCM with a lower increase in precipitation in the future.

In contrast to that we can also look at the GCM that predicts some of the greatest increases in precipitation in the future in the spring, and here you'll see that there's a lot more agreement, a little bit less variability. So you see that everything is coming in with a greater than 50% increase in bloom events, some as high as 85%. So everything here is between 50 and 85% increase. So hopefully I've shown you how we've gone through and looked at one specific climate model, the BCC model, and what we've tried to do here is bound things by looking at first of all the CANES model, which was a lower precipitation, predicts less gains in precipitation in the future, and shown you how that can affect HABs. We've also looked at the GCM which predicts higher gains in precipitation in the future, and shown that there's a consistently greater HAB events predicted in the future for greater amounts of precipitation.

So I'm going to wrap things up here. The first thing I want to do is that this is, what you've seen here is a portion of a larger project. So what we'd like to do in the future is link the model that we've shown here with models of farmer decision making and regional policy analysis. This is a project that's being sponsored by National Science Foundation and the Coupled Human and Natural Systems Program. So what we'd like to do is have what I've shown you today kind of be the worst-case scenario. So if we don't change anything on the landscape, this is what, this is where we expect HABs to be in the future. When we include some of the human decision making models with what I've shown you here today we hope to be able to look at how different BMPs and different management plans could counterbalance, could counterbalance impacts of climate change. So what I've shown you here today is highlighted with this, highlighted in yellow or shaded area here. So we've just looked at predicting climate change, how climate change will interact with the landscape to change the discharge of the Maumee River, and that will impact HABs. What we want to do in the future is look at how regional policy analysis of farmer decision making might change some of the practices on the landscape, and that could counterbalance some of the impacts of climate change to hopefully mitigate some of the impacts of HABs and other ecosystem services in LE. So I just wanted to point out that this was part of a larger project that we're pursuing here.

And with that I'll go on to conclusions for today. So overall we expect the frequency and extent of HAB events to increase in LE. This is due to increased precipitation and river discharger, and we looked at a number of different scenarios here, and we expect this to both happen under high and low emission scenarios. There is some variability here that I highlighted when we looked at the results. We also consider these predictions to be conservative. As I pointed out earlier there were three reasons why we expect HAB events to grow in the future, and we only looked at one of those causes today, and that was due to changes in precipitation and changes in nutrients coming into LE. We did not include changes in temperature and how that's going to affect the dynamics of the bloom. We did not, we also did not look at how changes in dissolved organic carbon and CO_2 will affect the dynamics of blooms, and both of those will probably increase the growth rate of these blooms. So we do consider these predictions to be conservative.

As always there's more research to do, so we only looked at three climate models. That's all we've looked at so far. What we want to do in the future is look at the remaining 33 climate models. And we hope that by doing this we can better assess the variability and get some better averages to know that there is a lot of variability here, but it's clear that these HAB events are going to grow or it's clear that they're not going to grow. What we've seen right now, it's clear that they are going to grow. One other limitation that we've identified and others have identified is that the HAB model that we're using it had very good results from 2000-2011. When we looked at 2012-2013 it did show some limitations there. So we're going to look at using other models to predict HABs, perhaps using phosphorus as I indicated before in addition to discharge to predict HABs. So we need to refine that a little bit.

And lastly I want to highlight kind of one of the main motivations for this research, so and that's to guide management plans. So some of you have probably heard about the recommendation to reduce phosphorus inputs into LE by 40% with the idea of reducing HABs. And that's a good recommendation, but it's based historically, it's based solely on historical trends. And we do know that the climate is going to change in the future. That's very clear to us. So in addition to basing our management plans on historical trends, we also need to be able to predict what's going to happen in the future and how LE and HABs are going to respond to changes in the future and take these changes into account when we develop management plans. And that's the main reason for this work, and we hope that this work can serve in that function to guide management plans and guidance to improve the future of LE.

So with that, I do thank everybody for tuning in. And if we do have time I'm happy to answer some questions. Thank you.

Great, thanks Dr. Martin! We've gotten a lot questions, so let me just get started and we'll start going through these. Could you talk a little bit more of why the Maumee Bay was chosen? We've gotten quite a few questions asking about the focus of the Maumee Bay watershed, and if that, if the model also considers the entire upper lakes' watershed and the impacts of the changes of the upper lake water flow and temperature of the western basin. So could you talk a little bit about why this watershed was chosen?

So the reason for the Maumee watershed, and I guess for western LE, so we're in Ohio so the Maumee River watershed is really important to us. But if you look at HAB events, that's really what's driving this work. The HAB events have been linked pretty well to what's coming out of the Maumee Basin. So I mentioned before that, let me see if I can get to that slide. So there's very good agreement that what comes out of the Maumee Basin is a big driver, the most important driver of what happens in western LE. And the reason for that is because the Maumee River contributes greater than, the greatest amount of phosphorus and nutrients and sediments to LE. It's a bit counterintuitive because what comes out of the Detroit River, which I'll highlight here, coming from the rest of the Great Lakes comes into the northern portion of the western basin of LE. That contributes of the bulk of the water, but that water that's coming from Detroit is very stable in the amount of nutrients that come in. So it's not very dynamic, whereas what comes out of the Maumee Basin can change pretty dramatically based on what happens in the spring, so what happened in 2011 is good evidence of that. 2011 we had our wettest spring here in Ohio, and we had the greatest HAB event we've ever seen. So what happens in western LE is really driven by what happens in the Maumee Basin, so that's really the reason we focused on the Maumee Basin.

Okay, thanks. We've had a couple of questions dealing with the Detroit and I guess can you talk a little bit more about that? I had one question in particular that said based on my understanding discharge of the Detroit would dilute nutrient and sediment loading of the Maumee River. Is it true that discharge of the Detroit is not related to the occurrence of HABs?

Well let me see how I can answer that. I think it's true that what comes out of Detroit would dilute what comes out of the Maumee because they mix in the western basin. I can't say that what comes out of the Detroit River, I cannot say what comes out of the Detroit River will not impact HABs. But there's very good evidence that HABs are much more correlated with what comes out of the Maumee and much less correlated with what comes out of the Detroit River. And a good evidence for that is the Stumpf model, which I highlighted here in this talk, and the Stumpf model shows pretty clearly that the extent, the size, the intensity of the HABs that we see in LE are very well related to what comes out of the Maumee. Just going back to the question I cannot say that what comes out of the Detroit River does not impact HABs at all. It probably does impact it somewhat.

Okay, thanks. We've gotten quite a few questions dealing with the model itself, and so let me just start rattling off some of these questions. First question is does the study, well, I guess this is a first question is not specific to the model, but does the study account for changes in agriculture practices?

No, it does not. And that's a very good point. So we started with land use map that we currently see on LE, that we currently see in the Maumee Basin, I'm sorry. So we start with the current land use in the Maumee Basin, which as I've said before is about 75% ag, and there's some urban areas and some forest areas and things like that. And then into the future, so all the way through 2099 we use that same map. We don't change any of the cropping practices. We don't change any of the rotations from soybean to corn. We don't change any of the management practices. So as I mentioned before we, what we hope is that this is kind of a worst-case scenario, so if we move into the future with the current land use, current management practices, these are the results we get. And what we want to do in the future, what we're going to do in the future is take, is put different management plans on that landscape map and see how we can counterbalance these impacts of climate change to hopefully improve or reduce the amount of HABs that we see in the future.

Okay. Another question that we had gotten was specifically dealing with changes in land use and land cover. Will that affect projections of rainfall?

Land use and land cover, will it affect predictions of rainfall? I do not believe so. The climate models, the regional climate models I do not believe have feedbacks with the landscape. I could be wrong about that, but the type of changes that we expect to see in this area are changes in cropping practices and management practices. And my opinion is those would not have much of an impact on precipitation. The precipitation that we're seeing, that we're predicting with these global climate models are impacted much more by global trends, by changes in CO_2 in the atmosphere, much more than they are by what's happening on the ground.

A couple other questions dealing specifically with the model. One was for the watershed model calibration, where is the field data coming from and where is the station located? As well as what is the resolution of these climate models?

So just a clarification, I think the first question was about the watershed model. Is that right?

Yes.

Okay, so I was remiss earlier. I forgot to thank my colleagues at Heidelberg University. They are the ones who compiled an excellent dataset from the Maumee Basin. And so they have a very good historical record of flows and water quality at Waterton, which is right here at Toledo. Okay, so we, this is where we compared the discharge predicted by the model with historical discharge at the outflow from the Maumee Basin. And can you remind me of the second question? I think that was about the climate models.

He was asking what the resolution, what resolution is used in these climate models?

That's an excellent question. So when you look at a global climate model the resolution is very coarse. So the whole Maumee Basin is actually split, usually split in between two cells of a global climate model. So that's where you start with the global climate model. That's new information here. So that's where you start. It's very coarse, coarse resolution when you start with the global climate model. What's important to know, and I've highlighted here in this slide is that these models are downscaled. So when you get that coarse resolution you can downscale those predictions to give you multiple predictions within the basin. So there's about ten precipitation predictions within the basin. That's kind of the scale we're at. Another important thing is that these models have been bias-corrected. So some of these climate models, when you compare them to what happens historically, they'll show an increase or decrease in precipitation compared to historical trends, and then you can correct for that bias so that hopefully you're getting a better prediction of what happens in the future. I hope that helps with the question.

Another question that we had was what sort of implications and/or recommendations does this research have for application and use of the fertilizer throughout the Maumee Basin?

Use of fertilizers throughout the Maumee Basin. So I think first of all it points to trying limit runoff events, runoff from happening so how can you keep more sediment on a field and eliminate runoff? That's first thing there because we're looking at discharge. Fertilizer, I mean the overall thing is how can you reduce the amount of phosphorus getting into the river, so if you could more optimally apply fertilizer, whether that's with precision agriculture or some other methods so that less of the fertilizer runs off during these rainfall events, so that's one way. And then another way is to catch the fertilizer that's running off before it gets to the streams and rivers. So can you use a buffer strip or wetland, so anyway that you can reduce runoff and reduce nutrients coming off of ag fields, that will be helpful.

A couple other questions before you go back into some of the model questions. Would the increased precipitation put, push the impacts or blooms experienced in the western basin into the central basin?

That could happen depending on how large the blooms are. What can also happen in the central basin is there could be other rivers that flow into the central basin, such as the Sandusky is getting close to the central basin. So we haven't done this modeling for the Sandusky, but the same trends could happen there. So that's possible. There's no way I can say that with much certainty, but it's definitely possible that that could happen.

Is it important to consider how sediment transport, which affects light availability, will also increase the increased precipitation?

So I think the question there is how will changes in precipitation affect the amount of sediment that discharges from the river. Is that correct?

I think so, yes.

So there's a pretty good correlation, not only with phosphorus and river discharge, but also with sediment and river discharge. So as the precipitation events, as the precipitation increases not only would we expect river discharge to increase, but we'd also expect sediment to increase. Does that answer that question?

I think so.

I mean there are some probably some important internal dynamics that are going happen in a lake with regards to phosphorus and sediment, so if you have a lot of sediment coming into a lake, that could reduce the amount of sunlight that's available for the HABs. But most of that sediment is going to fall out pretty early in the plume, in the very front of LE or very close to the discharge, whereas the soluble phosphorus is going to be available across the lake. So you know there's going to be some kind of dynamics there. There's definitely going to be more sediments if you have more river discharge, but I don't think it'll reduce the size of bloom events too much.

A couple more questions dealing with the model. Do the models have the capability of grid embedding in the area of interest, so a finer grid can be used for the area of interest?

No, they don't. The current model we have, the model from Stumpf et al., it just predicts an overall cyanobacterial index for LE. We have been looking into developing models that would predict, would better predict the spatial extent of the blooms and where the blooms might be, and where they might not be, but that's a long way away, I think. That's my opinion at least. Then you'd have to, in order to predict where the blooms are and how long they're going to last, more specifically you'd have to couple a lake dynamic model with what's coming out of the river discharge. So it's possible, that might be something to look at down the line, but right now we do not have that ability.

We had a question dealing with economic impacts. Would you be able to talk about some of the economic impacts of HABs, that HABs would have in this region? Could your results be used to quantify those economic impacts?

I mean, I know generally the economic impacts. So, you know, I talked about the drinking water plant being shut down, and the impacts on fisheries and beach use. So I think with maybe with some more research you could try to relate these results to economic impacts. I think we're maybe a little bit far away from that right now. The way I could think of doing that right now would be to look at past bloom events and the cyanobacterial index, and if we could relate those to economic impacts. So have some kind of correlation between cyanobacterial index each year, and economic impacts, then we could use that into the future to predict economic impacts, but I'd feel a little bit uncomfortable right now making specific predictions about economic impacts other than saying that, you know, larger and more frequent HAB events will have more drastic economic impacts, or more negative economic impacts.

Okay. Another question that we had was even if we could significantly expand and accelerate on-the-ground measures to reduce nutrients entering Maumee Bay, how long may it take to noticeably reduce algal blooms in LE given the residual nutrient level?

That's a really good question. My reply to that would be that what happens is that, my overall reply would be that it's hopeful. And the reason I say that is because based on what's happened in the last 11 years, there's good evidence that what happens in LE is due to what comes in from the rivers, much more than to what already exists in the lake. And the reason I say that is because if you look at what's happened historically, there's a great correlation between what's coming in from the river and what's happening in the lake. Again the Stumpf model shows this. So if there's a really low rainfall year, there's a very, a small bloom. Okay. If there's a big rainfall year, there's a big bloom. So that makes it clear that what happens in the watershed with regards to rainfall drives what happens in LE. If we didn't see that relationship and if what happened in LE was happening irregardless of what happens, or regardless of what happens in the watershed, then we might think it's more due to the build up of nutrients in the bottom of LE. So because there's this tight relationship between what comes from the Maumee River and what's happening in LE, this indicates that if we can change what's happening in the watershed, if we can change management practices, if we can limit the amount of phosphorus that comes into LE, we can reduce the size and reduce the frequency of these HAB events. So it's hopeful that we can make these changes in the future and reduce the frequency and size of HAB events.

I think we covered nearly the majority of the questions, and so I guess, the last question that I'd had several people ask is whether or not you feel the intense blooms that we're having now are tied directly to climate change?

Are they tied directly to climate change? I guess climate change has a role in them, I think, because if you look historically at the climate in the Maumee Basin, so there's a good climate record in the Maumee Basin from 1950 to present. If you look at those trends, there is a trend for more intense storms and for more spring rainfall. So, you know, what we saw in 2011 is a good example of that. 2011 was one of the wettest, if not the wettest year that we saw in the Maumee Basin. Because of that we had the greatest HAB event that we saw in the Maumee Basin, so I do think that climate change has a role in the increased frequency in the larger HAB events we're seeing now, yes.

Well thank you, Dr. Martin! We're actually out of time. I want to thank you again for your willingness to talk to us today, again, about your work. It was really a great discussion. Also, a thank you to Ohio State University, the National Sea Grant College Program, and Ohio Supercomputer for funding this webinar. I did want remind everyone that our survey url for this webinar is in the 'chat' feature. Please take a few minutes to fill that out. I also wanted to reference you to resources and an archive of all previous webinar presentations, which are located on our changingclimate.osu.edu website as well as our new regional website at greatlakesclimate.com. This webinar series is sponsored by the OSU Climate Change Outreach Team and we'll start up again in September with scientists from NOAA discussing NOAA climate resources that we can use and access. The registration is up in the 'chat'. Thank you again to Dr. Martin and to all participants on this webinar. We hope this was beneficial, and hope you'll join us again in an upcoming webinar. Thank you, and have a great afternoon. Thanks again, Dr. Martin!